

## Galer, Rose

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**From:** Rose, Jay  
**Sent:** Tuesday, December 18, 2007 9:56 AM  
**To:** Galer, Rose  
**Subject:** FW: high burnup write up-- Finck 2007b  
**Attachments:** high burn-up writeupver2.doc

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**From:** Phillip J Finck [mailto:Phillip.Finck@inl.gov]  
**Sent:** Monday, October 15, 2007 10:16 PM  
**To:** Rose, Jay; francis.schwartz@hq.doe.gov  
**Cc:** bwd@inl.gov; Roald Wigeland; kathryn.mccarthy@inl.gov  
**Subject:** high burnup write up

I made a few changes from Brent's version

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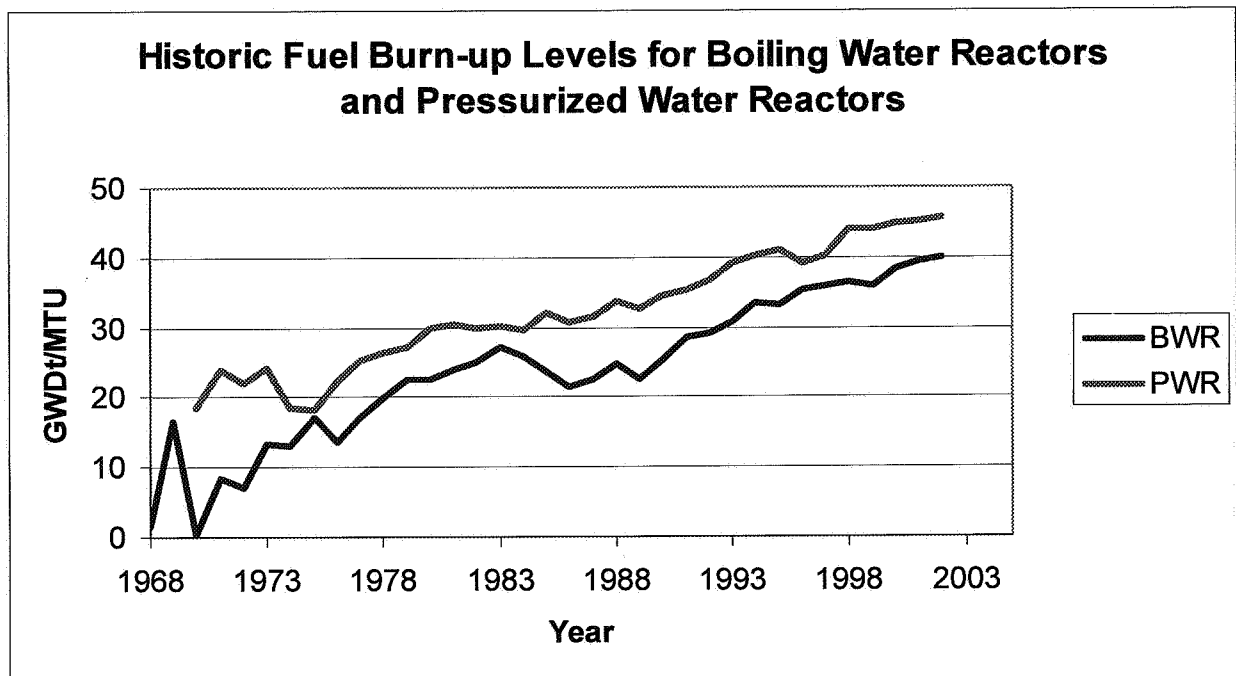
**Increased Burn-up<sup>[1]</sup> of LWR Fuels.** DOE considered a scenario in which LWR operations would significantly increase the burn-up of LWR fuel. Burn-up refers to the amount of energy generated per unit mass of fuel. Therefore, since fuel assemblies are of approximately equal mass, higher burn-up fuels can reduce the total amount of spent fuel generated by providing more energy per fuel assembly.

Historic U.S. commercial reactor operations show a steady trend toward higher burn-up (see Figure [X]). The average improvement over the last 20 years is about 1 GWdt/MTHM per year. This trend is expected to slow down in the future due to a number of practical limits. These include licensing and design limits on commercial enrichment plants, physical limits of fuel cladding, and operational cycle limits at the power plants to support preventative maintenance activities. The development work necessary to reach these higher burnup levels have been successfully handled by the commercial sector. Some have suggested that burn-up could eventually double from current values of ~50 GWd/MT.

Scenarios were considered in which burn-up would be doubled, which could cut the mass of future SNF in half for the same total energy generation. However, other important parameters do not change as significantly.

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Footnote 1: Burn-up is a measurement of the fissile material consumed via fissioning during fuel irradiation. It is normally quoted in either megawatt days per kilogram (MWd/kg) or gigawatt days per tonne (GWdt/MTU), where tonne refers to a metric ton of uranium metal or its equivalent. The unit GWdt/MTU is the (average) thermal output, multiplied by the time of operation, and divided by the mass of fuel involved. This gives a rough measure of the number of nuclear fission events that have taken place within the fuel.



**Figure X. Historic fuel burn-up levels for U.S. commercial boiling water reactors and pressurized water reactors.**

Higher burn-up requires higher enrichment (more fissile material) and therefore more natural uranium. The enrichment levels for 50 GWd/MT and 100 GWd/MT UOX fuel is 4.3% and 8.5% respectively, so the enrichment roughly doubles for doubled burn-up. For 1.0 MT of enriched uranium at these levels the natural uranium needs are 7.9 MT and 15.9 MT respectively (assuming 0.2% U-235 in the tails). Thus while more energy is produced per unit of fuel, the natural uranium resources needed stay roughly constant per unit of energy. The additional work required for enrichment offsets savings in fuel fabrication, so there is also little difference in fuel costs per unit of energy, and it is not clear where the economic optimum lies.

On the spent fuel side, doubling burn-up results in doubling of fission products per unit of fuel. However, transuranics in the spent fuel only increase by approximately 60% because some of the transuranics also fission. Section 1.3 identified three important technical parameters for repository disposal; spent fuel volume, radiotoxicity and heat load.

- At double the burn-up, only half as much spent fuel is produced and spent fuel volume per unit of energy produced is therefore reduced by 50%.
- Long-term radiotoxicity comes primarily from the uranium and transuranics present, along with fission product isotopes of technetium and iodine. The net impact is a reduction of long-term radiotoxicity per unit of energy produced of roughly 28%. However, since technetium and iodine are more mobile in the repository environment than uranium and transuranics, the reduction in off-site dose is estimated at less than 11%.
- Long-term heat load comes primarily from transuranics, with only limited contribution from fission products after the first 50-100 years. The net reduction in long-term heat per unit of energy produced when burn-up is doubled is roughly 15%.

Compared to the potential improvement factors of other alternatives, increased burn-up, by itself, would have a minor impact on improving the effective capacity of a geologic repository. As a result, increased burn-up using LWRs was eliminated from detailed study.